

**Climate Models: An Assessment
of Strengths and Limitations for
User Applications**

U.S. Climate Change Science Program

Lead Agency

Department of Energy (DOE)

Contributing Agencies

National Aeronautics and Space
Administration (NASA)

National Oceanic and Atmospheric
Administration (NOAA)

National Science Foundation (NSF)

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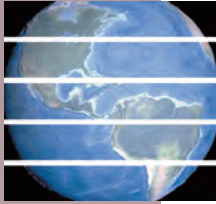
<http://www.climatechange.gov/>

This prospectus has been prepared according to the *Guidelines for Producing Climate Change Science Program (CCSP) Synthesis and Assessment Products*. The prospectus was reviewed and approved by the CCSP Interagency Committee. The document describes the focus of this synthesis and assessment product, and the process that will be used to prepare it. The document does not express any regulatory policies of the United States or any of its agencies, or make any findings of fact that could serve as predicates for regulatory action.

U.S. CLIMATE CHANGE SCIENCE PROGRAM

Prospectus for Synthesis and Assessment Product 3.1

Climate Models: An Assessment of Strengths and Limitations for User Applications



1. OVERVIEW: DESCRIPTION OF TOPIC, AUDIENCE, INTENDED USE, AND QUESTIONS TO BE ADDRESSED

Computer simulation models of the coupled atmosphere-land surface-ocean-sea ice system are essential scientific tools for understanding and projecting natural and human-caused changes in the Earth's climate. Coupled climate system models (called "climate models" herein) provide scientists a way to integrate their knowledge about elements of the climate system in a mathematical framework so that they can conduct computer simulations of the system.

The topics addressed by this Climate Change Science Program (CCSP) product are the strengths and limitations of climate models at different spatial and temporal scales. Its purpose is to provide this information on the strengths and limitations of the results from climate models, in ways that will allow the potential user of the information to evaluate how best it may be applied or not applied (*CCSP Strategic Plan*, page 19). This CCSP product will focus on natural and human-caused factors influencing climate variability and change during the period 1870-2000, and will seek to characterize sources of uncertainty in climate models and their implications on the uses and limitations of climate model results for future climate change. Discussion of specific future projections of climate will be limited in this product, because Synthesis and Assessment (S&A) Product 3.2 will deal with climate projections. This product will focus on the models and their sensitivity, feedbacks, and strengths and limitations, rather than future projections using these climate models.

The intended audiences of this CCSP product are decisionmakers and researchers who use climate model output as input to studies or analyses in their respective, non-climatic disciplines (e.g., ecosystem science, hydrology and water resources, economics, human health, and agriculture/forestry). In order to facilitate application and decisionmaking using information generated by climate models, an evaluation and assessment of limitations of state-of-the-science climate models is essential. This product is directed towards this goal. Users often need climate information at regional scales and Question 5 (see below) addresses issues related to dynamical downscaling of climate projections.

The intended use of this CCSP product is to provide information to those who use climate model outputs about the strengths and limitations associated with using models to project the potential effects of human activities on climate and sea-level rise. A discussion of appropriate and inappropriate uses of model output will be included. The product will address scientific issues on a comprehensive, objective, open, and transparent basis. While based on the peer-reviewed scientific literature, it will be written to be accessible and useful to the well-informed general reader and decisionmaker.

Specific questions to be addressed by this CCSP product follow:

- 1) *What are the major components and processes of the climate system that are included in present state-of-the-science climate models, and how do climate models represent these aspects of the climate system?* This section will include descriptions of crucial processes





such as tropical convection and major feedbacks in the climate system (e.g., clouds, atmospheric water vapor, surface albedo, and soil moisture). This section will evaluate the ability of the current generation of models to simulate key processes, and identify gaps in understanding. It will also include brief discussion of crucial processes that are likely to play an important role in climate that are not yet incorporated in the models.

2) *How are changes in the Earth's energy balance incorporated into climate models? How sensitive is the Earth's (modeled) climate to changes in the factors that affect the energy balance?* This section will explain current approaches for incorporating changes in radiative forcing from both natural and human factors since the pre-industrial era. These include changes resulting from greenhouse gas and trace constituent emissions into the atmosphere, volcanic eruptions, and variations in the sun's intensity. This section will present a brief overview of the response of the global climate system, as derived from climate model results, for the various forcings (e.g., solar, volcanic, aerosols, anthropogenically derived greenhouse gases). The relative contributions of natural variability and human-caused factors for the period under consideration will be examined.

[Note: S&A Product 2.3 will focus on aerosols and their relationships to climate change, so aerosols will be treated only briefly in this S&A Product 3.1.]

3) *How uncertain are climate model results? In what ways has uncertainty in model-based simulation and prediction changed with increased knowledge about the climate system?* This section will provide a discussion of the major sources of uncertainty in climate model results, as estimated through structured intercomparisons to observations, including the identification of the major sources of uncertainty in model assumptions and the characterization of radiative forcing. A description (or acknowledgement) of how increased knowledge can lead to greater uncertainty by increasing the number and complexity of processes included in climate models will be included.

4) *How well do climate models simulate natural variability and how does variability change over time?* The ability of climate models to simulate the climatology and

interannual variability is crucial for their use by the impacts and applications community. This section will describe efforts to evaluate these aspects of model performance. This section will also discuss the ability of climate models to simulate known patterns of natural variability, such as the Madden-Julian Oscillation, the El Niño Southern Oscillation, the North Atlantic Oscillation, and the Pacific Decadal Oscillation. A section on how these modes of variability have changed over time will be included.

5) *How well do climate models simulate regional climate variability and change?* This section will discuss how changes in certain regions (e.g., the North Atlantic or Tropical Pacific) can influence global climate change. It will also discuss limitations of “downscaling” methodologies—including regional climate modeling—used to obtain regional information from global simulations.

6) *What are the tradeoffs to be made in further climate model development (e.g., between increasing spatial/temporal resolution and representing additional physical/biological processes)?* This section will consider the opportunities and constraints on future model development (e.g., additional computational cycles and lack of process knowledge). It will outline prospects for improvements potentially important to policymaking and decisionmaking.

Answers to each of these questions will include descriptions of the spatial and temporal aspects of climate models as they relate to each of the questions—for example, how uncertainty at the mean annual global scale (e.g., mean annual global surface temperature) is related to uncertainty at a continental or sub-continental scale. Three variables—surface temperature, precipitation, and sea level—will be emphasized in this CCSP product because they are often considered by decisionmakers and non-climate scientists concerned with climate variability and change.

This CCSP product will be an “interpreted product” as that term is used in the information quality guidelines issued by the Department of Commerce and National Oceanic and Atmospheric Administration (NOAA). Namely, an



interpreted product is one that has "... been developed through interpretation of original data and synthesized products. In many cases, this information incorporates additional contextual and/or normative data, standards, or information that puts original data and synthesized products into larger spatial, temporal, or issue contexts. This information is subject to scientific interpretation, evaluation, and judgment. Examples of interpreted products include journal articles, scientific papers, technical reports, and production of and contributions to integrated assessments."

2. CONTACT INFORMATION: E-MAIL AND TELEPHONE FOR RESPONSIBLE INDIVIDUALS AT THE LEAD AND SUPPORTING AGENCIES

The Department of Energy (DOE) is the lead agency for this product. Participating agency contacts follow:

CCSP

<u>Agency</u>	<u>Agency Leads</u>
DOE	Dr. Anjuli Bamzai anjuli.bamzai@science.doe.gov (301) 903-0294
NASA	Dr. Donald Anderson danders1@hq.nasa.gov (202) 358-1432
NOAA	Dr. Ants Leetmaa Ants.Lleetmaa@noaa.gov (609) 452-6502
NSF	Dr. Jay Fein jfein@nsf.gov (703) 292-8527

3. LEAD AUTHORS: REQUIRED EXPERTISE OF LEAD AUTHORS AND BIOGRAPHICAL INFORMATION FOR PROPOSED LEAD AUTHORS

The list of lead authors is expected to include:

- Dr. David Bader/PCMDI Lawrence Livermore National Laboratory (coordinating lead author)

- Dr. Curtis Covey/PCMDI Lawrence Livermore National Laboratory
- Dr. William Gutowski/Iowa State University
- Dr. Isaac Held/NOAA GFDL
- Dr. Kenneth Kunkel/Center for Atmospheric Sciences Illinois State Water Survey
- Dr. Ron Miller/NASA GISS Columbia
- Dr. Robin Tokmakian/Naval Postgraduate School Monterey
- Dr Minghua Zhang/SUNY Stony Brook


Brief bios for each are provided in Appendix A. Additional lead and contributing authors will be finalized by the lead agency in consultation with the supporting agencies.

4. STAKEHOLDER INTERACTIONS

The intended audiences of this CCSP product are decisionmakers and researchers who use climate model output as input to studies or analyses in their respective, non-climatic disciplines (e.g., ecosystem science, hydrology and water resources, economics, human health, and agriculture and forestry). In order to facilitate application and decisionmaking using climate model information, an evaluation and assessment of the state of science of climate models is essential. This product is directed towards this goal. Users often need climate information at regional scales and Question 5 of the prospectus addresses issues related to dynamical downscaling of climate projections. The intended use of this CCSP product is to provide information to those who use climate model outputs about the current strengths and limitations associated with using models to project the potential effects of human activities on climate and sea-level rise. The product will address scientific issues on a comprehensive, objective, open, and transparent basis. While based on the peer-reviewed literature, it will be written to be accessible and useful to the well-informed general reader and decisionmaker.

In preparing this draft prospectus, careful consideration has been given to the feedback received from stakeholders at the December 2002 CCSP Planning Workshop for

ccsp product 3.1 prospectus



Scientists and Stakeholders. In addition, other recent developments have been reflected. For example, results from a workshop focusing on tropical biases that degrade projections have also guided the selection of topics to be covered in the product. The authors also intend to further shape the product with the input provided by scientists, decisionmakers, and general readers during the prospectus public comment period.

5. DRAFTING PROCESS (INCLUDING MATERIALS TO BE USED IN PREPARING THE PRODUCT)

The lead authors—organized by the coordinating lead author—will meet in person, through e-mail exchanges, and via teleconferences (as they see fit) to draft answers to the six key questions addressed in the product. They will also prepare an introductory section to describe the topic, the audience, and the intended use of this product. The coordinating lead author may assign primary responsibility for drafting the text associated with each question to a specific author. The lead authors will incorporate material from any contributing authors in the draft product as they see fit.

After the product is drafted, the lead authors (or coordinating lead author and the authors responsible for each of the six questions) will write a non-technical summary.

Lead and contributing authors will base all their writing on published, peer-reviewed scientific literature. Lead authors will consider the full range of relevant peer-reviewed information. The product and its non-technical summary will identify disparate views, where appropriate.

6. REVIEW

The public is invited to nominate Expert Reviewers to participate in the peer review of the draft S&A Product 3.1. Nominations should be sent to Dr. Anjali Bamzai (<anjali.bamzai@science.doe.gov>) by 31 March 2006;

reviewer nominations must include CVs and publications listings.

The lead agency will ensure that selected reviewers are technically qualified as demonstrated by scientific experience and published work. The lead agency will screen for real or perceived conflict of interest and independence from the lead and contributing agencies. The lead agency will ensure that the slate of reviewers reflects a balance of scientific/technical perspectives.

The review will follow the process described in the *Guidelines for Producing CCSP Synthesis and Assessment Products* (<www.climate.gov/Library/sap/sap-guidelines.htm>): (1) a first draft for expert peer review, (2) a second draft released for 45 days for public comment, and (3) a third draft for final review and approval through a Federal Advisory Committee Act (FACA) committee and the CCSP interagency committee and the National Science and Technology Council (NSTC). The expert peer review process will consist of independent written reviews from five to ten expert peer reviewers. The lead and supporting agencies will develop an appropriate charge for the reviewers.

Reviewers will be asked to use the following questions in formulating their comments on the draft product:

- 1) Is the purpose (i.e., topic, audience, intended use, and/or questions to be addressed) clearly described in the report? Are all aspects of the purpose fully addressed? Do the authors go beyond this purpose or their expertise?
- 2) Are the conclusions and recommendations adequately supported by evidence, analysis, and argument? Are uncertainties or incompleteness in the evidence explicitly recognized? If any recommendations are based on value judgments or the collective opinions of the authors, is this acknowledged and are scientifically defensible reasons given for reaching those judgments?
- 3) Are the data and analyses handled competently? Are statistical methods applied appropriately?
- 4) Are the report's exposition and organization effective? Is the title appropriate?

- 5) Is the report fair? Is its tone impartial and devoid of special pleading?
- 6) Does the executive summary concisely and accurately describe the key findings and recommendations? Is it consistent with other sections of the report?
- 7) Are signed papers or appendices, if any, relevant to the charge? If the report relies on signed papers to support consensus findings or recommendations, do the papers meet criterion 3 above?
- 8) What other significant improvements, if any, might be made in the report?

After receiving the reviews, the lead authors will revise the report as appropriate and prepare a response to the reviewers' comments. The peer review process will be consistent with the Final Information Quality Bulletin for Peer Review [*Federal Register*, Vol. 70, No. 10, January 14, 2005]. The Peer Review Plan for this Highly Influential Scientific Assessment is posted on the DOE web site at <www.science.doe.gov/informationtechnologymgmt/html/hisa.htm>. The report and response to reviewers' comments will then be posted for public review. Using the public comments, the lead authors will again revise the report as appropriate and prepare a response to reviewer comments of the public review.

A FACA committee will be established to oversee the preparation of the report. Following the public review, the FACA committee will review the report and the responses to peer review and public comments. Following the FACA committee review and subsequent revisions as necessary, the products will be passed to the CCSP interagency committee and NSTC for final approval and dissemination.

7. RELATED ACTIVITIES, INCLUDING OTHER NATIONAL AND INTERNATIONAL ASSESSMENT PROCESSES

This CCSP product will build on previous Intergovernmental Panel on Climate Change (IPCC) assessments (e.g., First, Second, and Third Assessment Reports) and other reports (e.g., *Climate Change Science:*

An Analysis of Some Key Questions). It is expected that this CCSP product will provide input to future National Research Council reports on climate models. This product is likely to draw from results emerging from the interagency Climate Model Evaluation Project (CMEP). CMEP activity is primarily to evaluate the IPCC model runs for the historical period 1870-2000.

8. COMMUNICATIONS: PROPOSED METHOD OF PUBLICATION AND DISSEMINATION OF THE PRODUCT


Once NSTC clearance has been obtained, the lead agency will coordinate production and release of the product with the CCSP Office (CCSPO) using the standard format for all CCSP S&A products. The final product and the comments received during the expert review and the public comment period will be posted on the CCSPO web site.

9. PROPOSED TIMELINE

2005	
Feb	Approved draft prospectus posted on CCSPO web site, and lead and contributing authors selected by lead agency
Mar	Public review; authors incorporate public comments in draft prospectus
Jun	Peer Review Plan posted on agency web site
Nov	Internal review of draft prospectus; draft prospectus sent to CCSP Principals for concurrence
2006	
Jan	Concurrence by CCSP Principals; final prospectus posted
Jan-Jun	Preparatory work towards draft report written by lead authors, with input from contributors
June	FACA committee meeting to discuss draft report and get feedback
July-Aug	Finalize Version 1 to be sent out for peer review



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Aug Report sent out for peer review by lead agency
Oct Version 2 based on peer review comments
Nov FACA committee teleconference (exact date TBD), with any outstanding issues on Version 2 discussed
Nov-Dec Version 2 posted for public comment on CCSP/agency web site

2007

Jan-Feb Version 3 prepared based on public comments
Mar FACA committee meeting (either phone or in person); finalize Version 3 and send final report to DOE
Mar DOE posts FACA report on web site; DOE sends FACA report to CCSP Principals
Apr Concurrence by CCSP Principals and NSTC clearance
May Lead agency produces final product according to format provided by CCSP
May On-line version of report released; lead agency coordinates with CCSP
Jul Hardcopy version of report released; lead agency coordinates with CCSP

APPENDIX A—Bios for Potential Lead Authors**DAVID BADER**

Dr. David C. Bader received his Ph.D. (Atmospheric Science) in 1985 from Colorado State University. Since June 2003, he has been Director, Program for Climate Model Diagnosis and Intercomparison, which coordinates major international climate model evaluation and intercomparison activities for the World Climate Research Programme. He is also Chief Scientist for the U.S. Department of Energy's Climate Change Prediction Program. From 1990 to 2002, he developed and managed climate modeling and computational research programs for DOE's Office of Science, and was the agency's principal representative for climate research and climate modeling to interagency working groups and committees. He was a lead author of the interagency *U.S. Climate Change Science Program Strategic Plan* Chapter 10 on Modeling Strategy, and in 2001 was chair of the interagency Climate Change Research Initiative (CCRI) Working Group on Climate Modeling. He was the U.S. Government review coordinator of the climate model evaluation chapters in the Working Group I contributions to the IPCC Second Assessment Report and Third Assessment Report.

CURTIS COVEY

Dr. Curtis C. Covey is a physicist at the Lawrence Livermore National Laboratory (LLNL). He received a Ph.D. in Geophysics and Space Physics from the University of California, Los Angeles, in 1982. He joined LLNL in 1987, after a postdoctoral fellowship at the National Center for Atmospheric Research and an assistant professorship at the University of Miami. He has spent most of his time at LLNL working for the Program for Climate Model Diagnosis and Intercomparison, where he maintains the database for the Coupled Model Intercomparison Project (CMIP). He has written or co-authored about 80 papers on climate modeling, climate change, and extraterrestrial atmospheres. He has served as an editor for the journal *Global and Planetary Change*, as a Lead Author for the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report, and as a member of the World Climate Research Programme Working Group on Coupled Modeling Climate Simulation Panel, which is providing data for the IPCC's forthcoming Fourth Assessment Report.

WILLIAM GUTOWSKI

Dr. William Gutowski is a professor of meteorology at Iowa State University. He received a Ph.D. in Meteorology from M.I.T. in 1984. He joined Iowa State in 1991 as an assistant professor after working at Atmospheric and Environmental Research, Inc., for several years. With colleagues at Iowa State, he has directed the Project to Intercompare Regional Climate Simulations (PIRCS). He has also been an invited consultant for regional-climate modeling programs in Africa, Asia, South America and the Arctic. His work also includes fostering a climate research community in Africa. He has authored or co-authored about 50 peer-reviewed publications on atmospheric dynamics, water cycle processes, climate simulation and climate change. He has served on the editorial board of *Dynamics of Atmospheres and Oceans* and as a contributing author to chapters in regional climate in the IPCC Third and upcoming Fourth Assessment Reports.

ISAAC HELD

Dr. Isaac Held is a Senior Research Scientist at NOAA's Geophysical Fluid Dynamics Laboratory, where he conducts research on climate dynamics and climate modeling, and is head of the Weather and Atmospheric Dynamics Group. After receiving his Ph.D. at Princeton University, and after a short stint at Harvard University, he joined GFDL in 1978 and has remained there ever since. He is also a lecturer with rank of Professor at Princeton University, in its Atmospheric and Oceanic Sciences Program, where he has supervised over a dozen Ph.D. theses. He also serves as an Associate Faculty member in Princeton's Applied and Computational Mathematics Program and in the Princeton Environmental Institute, and has taught at Woods Hole Oceanographic Institution. Dr. Held is a Fellow of the American Meteorological Society (1991) and the American Geophysical Union (1995), and a member of the National Academy of Sciences (2003). He has received the Meisinger Award of the AMS (1987) for "outstanding contributions to the study of climate dynamics..." the Bernhard Haurwitz Memorial Lectureship of the AMS (1999), the Rosenstiel Award from the University of Miami (1994) "for breadth and incisiveness in attacking fundamental problems of geophysical fluid dynamics, the general circulation of the atmosphere, and climate dynamics," and the Department of Commerce Gold Medal (1999) "for world leadership in studies of climate dynamics."

KENNETH KUNKEL

Dr. Kenneth Kunkel is Director of the Center for Atmospheric Sciences of the Illinois State Water Survey (a division of the Illinois Department of Natural Resources and an affiliated agency of the University of Illinois at Urbana-Champaign). The Center performs research and outreach on climate variability and change, regional climate and air quality modeling, small-scale atmospheric phenomena, and atmospheric chemistry, with a particular emphasis on Illinois and Midwest U.S. issues. He served as Director of the NOAA Midwestern Regional Climate Center for 10 years. He is also an adjunct Professor with the Department of Atmospheric Sciences of the University of Illinois. He holds a B.S. in physics from Southern Illinois University and an M.S. and Ph.D. in meteorology from the University of Wisconsin-Madison. He is a Fellow of the American Meteorological Society. His recent research has focused on climate variability and extremes, regional climate modeling, and regional climate applications. He has recently served on review and advisory panels for the National Research Council, Environment Canada, the National Center for Atmospheric Research, the Program for Climate Model Data and Intercomparison, and the United States Climate Reference Network.

RON MILLER

Ron Miller received his Ph.D in Meteorology in 1990 from the Massachusetts Institute of Technology. Since then, he has been at the NASA Goddard Institute for Space Studies in New York City, where he is a Physical Scientist. His research interests include tropical climate as well as the effect of soil dust and other aerosols on present and past climate. He is an adjunct professor in the Department of Applied Physics and Applied Math at Columbia University.

ROBIN TOKMAKIAN

Dr. Robin Tokmakian is a research associate professor in the Department of Oceanography at the Naval Postgraduate School (NPS). She received her Ph.D. in physical oceanography from the Naval Postgraduate School and an M.S. in oceanography from Oregon State University and a

B.A. in physics from the University of California, Santa Barbara. Prior to joining NPS, she was a researcher with the James Rennell Centre, a division of the Institute of Oceanographic Sciences, UK, now known as the National Oceanography Centre. She has served on the International Scientific Committee on Oceanic Research (SCOR) Working on Ocean Bathymetry and a working group on an international working group on surface salinity. Her research is focused on the use of high-resolution, coupled ocean/ice primitive equation models to understand the ocean's variability up to decadal scales. The research includes the evaluation of the realism of such models through the synergistic use of observational data such as that measured by satellites and hydrographic surveys. She has been a participant or collaborator on international projects such as the World Ocean Circulation Experiment (WOCE) and the UK's RAPID Climate Change program.

MINGHUA ZHANG

Dr. Minghua Zhang is a professor and Director of the Institute for Terrestrial and Planetary Atmospheres of the State University of New York at Stony Brook. He is also the Associate Dean of the Marine Sciences Research Center of the university. After receiving his Ph.D. in 1987 at the Institute of Atmospheric Physics of the Chinese Academy of Sciences, he joined the Stony Brook University as a postdoctoral associate, assistant professor, associate professor and full professor of Atmospheric Sciences, and has remained there ever since. His research includes climate modeling and evaluation of climate models. He has published over sixty peer-reviewed papers on these subjects. He is a principal investigator of the NASA Tropical Rainfall Measuring Mission, of the DOE Atmospheric Radiation Program, and the Climate Dynamics Program of the National Science Foundation. He co-chaired the Cloud Parameterization and Modeling Working Group of the DOE Atmospheric Radiation Measurement Program. He received the Young Faculty Career Award from the National Science Foundation.